CHAPTER 4
POTENTIAL LARGE-SCALE IMPACTS OF STUDY VESSELS' INCIDENTAL DISCHARGES TO HUMAN HEALTH AND THE ENVIRONMENT

In Chapter 3, EPA described the variety of vessel discharges and the scope and magnitude of pollutants discharged by 'study vessels.' EPA discussed whether these discharges of pollutants exceeded a National Recommended Water Quality Criteria (NRWQC) at end-of-pipe or contained persistent bioaccumulative toxic (PBT) chemicals which could indicate a potential for environmental effects. Public Law (P.L.) 110-299 tasks EPA with assessing the potential for discharges incidental to the normal operation of vessels to pose a risk to human health, welfare, or the environment from all sizes of commercial fishing vessels and other nonrecreational vessels less than 79 feet in length. As part of this assessment, EPA used a screening-level model as a tool to evaluate the cumulative effects of discharges from a population of such vessels operating in a large receiving water body.

EPA developed the screening-level water quality model to assess the impacts of vessel discharges on a hypothetical harbor environment[1]. For purposes of the model, EPA developed several vessel population scenarios that included multiple vessels from numerous vessel classes, such as fishing vessels, tour boats, water taxis, and tugboats discharging various waste streams (e.g., antifouling leachate, bilgewater, engine effluent, graywater). EPA then modeled numerous scenarios combining the different vessel populations in different hypothetical harbors to represent a range of environmental conditions potentially observed in harbors across the United States.

Due to the limitations of this screening-level model, EPA assumed that the background concentration for all analytes in the harbor water was zero. Although this assumption is likely unrealistic, removing other loading considerations from model calculations allowed EPA to evaluate whether incidental discharges from study vessels alone have the potential to exceed National Recommended Water Quality Criteria (NRWQC) in receiving waters without any additional sources of pollution. Vessel discharges may have a potential to contribute to water body impairment when vessel discharge pollutant concentrations exceed the NRWQC at end-of-pipe, depending on the quantity of pollutant in the discharge, what other potential sources of pollution are present, and the characteristics of the waters in which the vessel is operating. For example, if a group of vessels contributes a significant quantity of a given pollutant via a

[1] For this analysis, the "harbor environment" refers to a large body of water that could potentially have 175 to 300 commercial vessels simultaneously discharging. EPA assumed that the harbor area extended beyond the defined vessel docking area to include the surrounding water body with an estimated surface area ranging from one to three square miles.

discharge into a water body, the impact of the vessel discharge is more likely to contribute to a water quality exceedance. If a group of vessels contributes only a very small quantity of a given pollutant via a discharge, the impact of the vessel discharge is less likely to contribute meaningfully to a water quality exceedance. EPA believes that assessing the potential for vessel discharges to contribute to water-body impairment is best conducted on a site-specific basis and is beyond the scope of this screening-level analysis.

Based on this assessment, EPA determined that incidental discharges from study vessels do not solely cause any NRWQC to be exceeded in the modeled hypothetical large estuaries and harbors. This determination suggests that these discharges alone are unlikely to cause impairments to relatively large water bodies. However, if a large water body already contains select pollutants, then vessels that contribute significant quantities of these pollutants might contribute to such an NRWQC exceedance. Furthermore, as discussed in Chapter 3, many pollutants detected in the vessel discharges were present at concentrations that exceed an NRWQC at the end of pipe, and therefore have the potential to negatively impact the receiving water on a more localized scale. Because the screening model assumes instantaneous and universal dilution in a large hypothetical harbor, the model is not designed to examine impacts on a local scale, in small water bodies with many vessels, or in water bodies with little to no flushing (i.e. dilution). These discharges may cause environmental concerns in areas such as small side embayments or marinas where flushing rates are low (see discussion in Section 4.6). As discussed above, EPA further notes that this model does not take into account any loadings from vessels that are not study vessels or other point/nonpoint sources that discharge pollutants that contribute to the loadings in the water body.

For the purpose of this study, EPA selected a simple screening-level model to provide a coarse "big picture" assessment of the overall potential for discharges from study vessels to cause or contribute to an impact on human health, welfare, or the environment. Although a screening-level model has several limitations, it identifies any major water quality issues, provides valuable information on pollutants of concern, identifies data gaps, and serves as a starting point for any future site-specific studies that are beyond the scope and objectives of this study.

The remainder of this chapter details EPA's cumulative effects assessment and is organized as follows:

- Section 4.1: Model Selection - Presents EPA's rationale for selecting the Fraction of Freshwater Screening-Level Model for the analysis.

- Section 4.2: Fraction of Freshwater Model - Describes the "fraction of freshwater model" and presents the equations and input parameters required for the screening-level analysis.

- Section 4.3: Vessel Discharge Loading Rates - Describes the methodology for developing the input parameters required to calculate the total analyte-specific loading rates for each vessel population scenario.

- Section 4.4: Hypothetical Harbor - Describes the methodology for developing hypothetical harbor input parameters.

- Section 4.5: Model Scenarios - Presents the 24 model scenarios represented in the model.

- Section 4.6: Model Results - Presents the results from the "fraction of freshwater model."

- Section 4.7: Conclusions - Presents EPA's conclusions on the potential for vessel discharges from study vessels to solely impact large-scale harbors or estuaries (e.g., to solely pose a risk to human health, welfare, and the environment).

4.1 MODEL SELECTION

Study vessels discharge into coastal harbors throughout the United States. Estuarine models, which are commonly used to assess harbor water quality, consist of two primary components: hydrodynamics (i.e., water transport processes) and water quality. Estuarine models are generally classified into the following four levels according to the temporal and spatial complexity of the hydrodynamic component of the model:

- Level I - Desktop screening models that calculate seasonal or annual mean concentrations based on steady-state conditions and simplified flushing time estimates.

- Level II - Computerized steady-state or tidally averaged quasi-dynamic simulation models, which generally use a box or compartment-type network.

- Level III - Computerized one-dimensional (i.e., estuary is well-mixed vertically and laterally) and quasi-two-dimensional (i.e., a link-node system describes estuary longitudinal and lateral mixing) dynamic simulation models.

- Level IV - Computerized two-dimensional (i.e., represents estuary longitudinal and lateral mixing) and three-dimensional (i.e., represents estuary longitudinal, lateral, and vertical mixing) dynamic simulation models (EPA 2001).

The sheer number of different coastal harbor environments potentially impacted by these vessels precludes using the more complex and data-intensive Level II, III, and IV models for the cumulative impacts analysis. For these reasons, EPA selected a Level I screening-level model, the "fraction of freshwater model," for the environmental assessment of vessel discharges from study vessels.

In addition to coastal harbors, study vessels also discharge to freshwater environments such as the Great Lakes and major river systems (e.g., Mississippi River). The "fraction of freshwater model" is applicable to only estuarine or saltwater-influenced environments; therefore, the modeling approach presented in this chapter does not address the potential environmental impact of vessel discharges in completely freshwater environments. Additional screening-level modeling approaches would be required to assess possible impacts of vessel discharges in these environments. EPA assumes that discharges to freshwater systems represent a smaller percentage of the total load from study vessels based on hailing port information provided in the Marine Information for Safety and Law Enforcement (MISLE) database maintained by the U.S. Coast Guard. Based on these data, commercial fishing vessels are almost exclusively located along U.S. coastal waters, and only about a third of other nonrecreational vessels less than 79 feet in length cite an inland waterway as their hailing port.

4.2 FRACTION OF FRESHWATER MODEL

The "fraction of freshwater model" is a series of equations that represent the harbor environment in zero dimensions and at a steady state (USEPA, 2001). These calculations are zero-dimensional in that they estimate concentrations at a given point in a water body within a specified, spatially homogenous volume. For example, the calculations assume instantaneous and homogeneous mixing of vessel discharges within the defined volume of a given harbor. It does not account for gradients of concentrations that would occur with distance from discharge source(s) such as plumes from vessels and other sources[2]. Specifying plumes and accounting for locations of numerous discharge sources would require a two- or three-dimensional model, which is beyond this Level I screening-level analysis.

Steady state means that the calculations provide an instantaneous estimate of the concentration under the assumption of chemical and physical equilibrium. Chemical equilibrium means that the water body salinity and the vessel discharge analyte concentrations do not change over time, while physical equilibrium means that the volume of water in the water body, tides, currents, and vessel discharge flow rates do not change over time. The assumption is that every process occurs instantaneously; therefore, temporal variability is not a factor. Accounting for changes in tides, currents, river flow, vessel discharge flow rates, and discharge concentrations over time would require a dynamic model, which is beyond this Level I screening-level model. This aspect of the model may cause it to underestimate localized environmental impacts,

[2] Discharge plumes can be highly structured, especially in low-flushing environments; therefore, the development of a worst-case scenario using a screening-level model is not entirely conservative due to the assumptions of instantaneous and homogenous mixing within the entire volume of the harbor. A true worst-case scenario would likely include the concentration of pollutants within a small area of the harbor due to minimal dispersion of discharge plumes across the harbor. It would also include background concentrations and take other pollutant loadings into account (e.g., sewage treatment facilities, recreational vessels and other large vessels, stormwater, agricultural runoff).

especially in areas with inadequate flushing. However, in estimating quantities of pollutants discharged from the various discharge types, EPA has tended to use conservative parameter estimates (i.e., estimates that may overstate the average value) for variables such as flow and pollutant concentration.

The "fraction of freshwater model" calculates the analyte concentration in a harbor resulting from vessel discharges using the following four steps:

- Step 1: Calculate vessel discharge analyte loading rates (Equations 4-1 and 4-2)
- Step 2: Calculate the fraction of freshwater in the harbor (Equation 4-3)
- Step 3: Calculate the harbor flushing time (Equation 4-4)
- Step 4: Calculate the harbor analyte concentration (Equation 4-5)

The following subsections describe the input requirements, assumptions, and calculations for each step in the "fraction of freshwater model."

4.2.1 Step 1: Calculate Vessel Discharge Analyte Loading Rates

Analyte-specific total discharge loading rates (W_e) are required as input values in the "fraction of freshwater model" to calculate the instantaneous analyte concentrations in the harbor (C_x). In this analysis, analyte loading rates were based on the following four input parameters:

- Average analyte concentrations for each vessel class discharge type;
- Estimated flow rate for each discharge type within a vessel class;
- Number of vessels per vessel class present in the harbor; and
- Percentage of vessels per vessel class discharging each discharge type in the harbor (Equation 4-1).

$$W_{e,z} = \Sigma(C_{e,y,z} * Q_{y,z} * N_{,z} * P_{y,z}) \qquad \text{Equation 4-1}$$

Where:

$W_{e,z}$ = Discharge loading rate for analyte e from vessel class z (mass/time)

$C_{e,y,z}$ = Average concentration of analyte e in discharge y from vessel class z (mass/volume)

$Q_{y,z}$ = Flow rate for discharge y from vessel class z (volume/time)

$N_{,z}$ = Number of vessels in vessel class z present in the harbor

$P_{y,z}$ = Percentage of vessels in vessel class z discharging discharge y

EPA calculated the analyte-specific total discharge loading rate by summing the discharge loading rates for that analyte from each vessel class (Equation 4-2). Section 4.3 describes EPA's methodology for calculating this loading rate in more detail.

$$W_e = \Sigma(W_{e,z}) \qquad \text{Equation 4-2}$$

Where:

W_e = Total discharge loading rate for analyte *e* from study vessel discharges (mass/time)

$W_{e,z}$ = Discharge loading rate for analyte *e* from vessel class *z* (mass/time)

4.2.2 Step 2: Calculate the Fraction of Freshwater in the Harbor

The "fraction of freshwater model" estimates analyte concentrations in one dimension using information on freshwater inflow and by comparing salinity in the harbor with salinity in the seawater at the mouth of the harbor (USEPA, 2001). The fraction of freshwater (f_x) at any location in the estuary is calculated as:

$$f_x = (S_s - S_x)/S_s \qquad \text{Equation 4-3}$$

Where:

f_x = Fraction of freshwater at location *x* in the model harbor (unit-less)

S_s = Seaward boundary salinity at the mouth of model harbor (PSU)

S_x = Salinity at location *x* in model harbor (PSU)

EPA states that this ratio (f_x) "…can be viewed as the degree of dilution of the freshwater inflow (as well as pollutants) by seawater" from tidal influx in the harbor (USEPA, 2001).

4.2.3 Step 3: Calculate the Harbor Flushing Time

Harbor flushing time is defined as the amount of time required to replace the freshwater volume of the harbor by the river freshwater input. The flushing time (t) of the model harbor is calculated using Equation 4-4:

$$t = (\mathrm{V} * f_x)/\mathrm{Q}_{\mathrm{fw}} \qquad \text{Equation 4-4}$$

Where:

t = Model harbor flushing time

V = Volume of model harbor

f_x = Fraction of freshwater at location *x* in model harbor (unit-less)

Q_{fw} = Inflow of freshwater to model harbor from the model river (volume/time)

4.2.4 Step 4: Calculate the Harbor Analyte Concentration

The concentration of an analyte at location x (C_x) is the analyte-specific total loading rate (W_e in mass/time) divided by the flow rate away from location x, described by the volume of the harbor (V) divided by the flushing time (t) (USEPA 2001):

$C_x = W_e/(V/t)$ Equation 4-5

Where:

C_x	=	Instantaneous analyte concentration at location x in model harbor (mass/volume)
W_e	=	Analyte-specific loading rate (mass/time) as calculated under Step 1
V	=	Volume of the model harbor as defined in Step 3
t	=	Model harbor flushing time as calculated in Step 3

4.3 VESSEL DISCHARGE LOADING RATES

Step 1 in the "fraction of freshwater model" calculates a range of analyte-specific total loading rates (W_e in mass/time) from fishing and nonrecreational vessels less than 79 feet based on the analyte concentration in a given discharge, the estimated flow rate for a given discharge, and assumptions on the number of vessels present in a harbor and percentage of vessels discharging each discharge type in the harbor. The following subsections present EPA's methodology for developing the modeling input parameters to calculate the analyte-specific total discharge loading rate.

4.3.1 Calculate the Average Analyte Concentrations

As described in Chapter 2, EPA collected wastewater characterization data for nine vessel discharges sampled from a total of 61 vessels (See Table 2.1). The objective of EPA's sampling program was to provide information on the nature, type, and composition of discharges from representative single study vessels and study vessel classes. EPA calculated vessel-class-specific analyte concentrations by averaging all of the discharge effluent sampling data by discharge type and by analyte. Replicate samples from a single vessel were averaged together prior to calculating a vessel-class-specific average. Certain analytes were not detected above the sample reporting limit in some wastewater samples. To fully represent the variability of pollutant concentrations in vessel discharges, EPA included both nondetected and detected results in calculating average vessel-class-specific analyte concentrations. For nondetected results, EPA assumed the analyte concentration was equal to one-half the sample reporting limit for that analyte. EPA based this assumption on the expectation that the analyte was present in wastewater, albeit at a concentration less than the sample reporting limit.

4.3.2 Discharge Flow Rate Assumptions

EPA calculated discharge-specific flow rates for each of the 59[3] study vessels sampled based on the following information for each discharge type:

- Known or estimated flow rates for the pump or mechanism controlling the discharge
- Assumptions on the frequency of discharge
- Assumptions on the duration of the discharge

EPA estimated vessel-specific discharge flow rates based on data and field observations from EPA's vessel sampling program, as well as information from secondary data sources. EPA developed frequency and duration assumptions based on interview responses from the vessel crew or observations from EPA's vessel sampling team. For example, EPA reviewed interview responses from a tow/salvage vessel operator to estimate bilge discharges based on the observation that the bilge pump discharges 60 gallons per minute for an approximate duration of five seconds per pump-out with an average frequency of one pump out every 10-minutes. As another example, the frequency at which fishing vessels discharge fish hold water into a harbor is generally dictated by how often the vessel offloads its catch. EPA used vessel sampling team field observations to develop the discharge frequency for each fishing vessel subclass (Table 4.3.1).

In addition, many of the study vessel classes discharge different amounts in different seasons. For example, fishing vessels operate during certain times of the year to coincide with different peak fishing seasons. As a conservative estimate, to account for the seasonal nature of these discharge loadings, EPA developed vessel flows to represent the loading rate that would typically occur during peak vessel activity for each vessel class. Specifically, EPA calculated the loading rates to represent the summer (or peak) season for all vessels, which is the time of greatest fishing activity in the major harbors across the United States and is generally the peak of recreational and tourist activity. [4]

[3] As previously discussed, EPA excluded the sampling data from the two recreational vessels in the model because these vessels are not study vessels.
[4] Vessel flow rates presented in the screening-level analysis are not intended to be used to estimate annual loads. Additional seasonal considerations, such as the length of different fishing seasons, are required to calculate annual loads, which is beyond the scope of the screening-level analysis.

Table 4.3.1. Offload Frequency by Fishing Vessel Subtype

Fishing Vessel Subclass	Frequency of Offloads[1]
Purse Seiners	Daily
Trollers	Daily
Gillnetters	Daily
Tenders	Once every 2 days
Longliners	Once every 2 days
Shrimpers	Once every 3 days
Trawlers	Once every 3 days

(1) Based on sampling team observation in the field.

Table 4.3.2 provides examples of the known or estimated field data parameters and assumptions used to calculate the vessel-specific discharge flow rates for each discharge type. Where data parameter information were unknown, EPA used information from a similar vessel discharge type or used best professional judgment to estimate the required information. Appendix G provides a detailed description of the data and assumptions used to calculate the discharge-specific flows for each of these 59 sampled vessels. EPA averaged the vessel-specific discharge flows presented in Appendix G by vessel class and discharge type to calculate the vessel class-specific flow rates ($Q_{y,z}$) used in the model (Table 4.3.3).

Table 4.3.2. Examples of Field Data and Assumptions for Flow Rate Calculations by Discharge

Discharge Type	Example Data Parameters	Example Assumptions	Example Discharge Flow Calculation
Bilgewater	- Flow rate of bilge pump - Frequency of bilge pump out - Duration of a single pump out	- 12 volt bilge pump at 20 gpm[1] - Discharged all year - 5 min to pump bilge - 2 pumpouts per day	- 5 min to pump bilge - 1 pump per week - Discharged 365 days a year - 12 volt bilge pump at 20 gpm 20 gal per min X 5 min X 1 pump/7 days = 14.3 gal/day (0.05 m^3/day)
Deck Wash	- Volume of water used during deck wash down - Frequency of deck washes - Duration of deck washes - Flow rate of garden hose or high-pressure sprayers used to wash decks	- Garden hose flow rate is 11.67 gpm[2] - 1 wash every 2 weeks - 15 minutes per deck wash	- Cleaned with hose - 15 minute per deck wash - Garden hose flow rate is 11.67 gpm - 1 wash every 2 weeks 11.67 gal per min X 15 min X 1 wash/14 days = 7.21 gal/day (0.03 m^3/day)
Fish Hold	- Volume of holding tanks - Volume of fish - Whether the tanks hold fish in water or ice - Amount of ice - Frequency of offloads - Length of fishing season	- Density of fish is 0.9 kg/liter - Holding tank is 70% shrimp, 30% water[3] - Ice tank holds 50% fish, 35% ice, 15% air[4]	- 5,000-gallon tank - 75% full at offload - Holding tank is 70%shrimp, 30% water - 1 offload every 3 days 5000 gal X 30% X 3/4 full X 1offload/3 days = 375 gal/day (1.42 m^3/day)
Fish Hold Clean	- Frequency of tank cleanings - Length of fishing season - Washed with garden hose	- 30-minute wash for tenders and purse seiners - 15-minute wash for all other fishing vessels - Wash done after each offload - Garden hose flow rate is 11.67 gpm	- 15-minute hose down after each offload - 1 offload every 3 days - Garden hose flow rate is 11.67 gpm 11.67 gal per min X 15 min X 1 wash/ 3 day = 33.66 gal/day (0.13 m^3/day)
Graywater	- Number of crew onboard - Types of graywater generated - Frequency of laundry washed - Frequency of showers	- Laundry – front-load washer uses 25 gal/load - Laundry - standard washer uses 40 gal/load - Shower - 17.2 gal per shower[5] - Shower - 0.8 showers per person per day[5] - Sink - 30 min of sink use per crew per week - Sink - 2.2 gal per min in standard sink	- 3 crew - 17.2 gal per shower - 0.8 showers per person per day 3 crew X 17.2 gal per shower X 0.8 showers per person per day = 41.28 gal/day (0.16 m3/day)

Table 4.3.2. Examples of Field Data and Assumptions for Flow Rate Calculations by Discharge

Discharge Type	Example Data Parameters	Example Assumptions	Example Discharge Flow Calculation
Generator Engine	- Engine type - Cooling system type - Hours of use per year	- 2 gpm cooling flow for a standard generator[6]	- 17,000 hours over 15 years - 2 gpm cooling flow 2 gal/min X 60 min/hr X 17000hrs/15 years/365 days = 372.6 gal/day (1.41 m3/day)
Propulsion Engine	- Engine type - Cooling system type - Hours of use per year - Number of engines onboard	- 1 gpm cooling water flow rate for outboard engine - 20 gpm cooling water flow rate for inboard engine[6]	- Cummins inboard 380hp diesel engine - 463 hours in last 2 years - 20 gpm cooling water flow rate 20 gal per min X 231.5 hours/year = 761.1 gal/day (2.88 m^3/day)
Shaft Water	- Duration of boat operation	- 10 mL/min constant drip (3.8 gal/day drip)[4]	- operates 5 days/week - 10 mL/min constant drip (3.8 gal/day drip) 3.8 gal per day X 5 days/week = 2.71 gal/day (0.01 m^3/day)

(1) Estimate based on commonly used 12-volt bilge pumps. Flow rates ranged from 5 gpm to 30 gpm via Google.
(2) EPA used http://www.uiweb.uidaho.edu/extension/lawn/Files/Garden_Hose.htm to calculate the average flow rate of a garden hose (i.e., 11.67 gpm). EPA calculated the flow rate as the average flow for all three sizes of standard garden hose (1/2, 5/8, and 3/4 inches in diameter), assuming a water pressure of 40 PSI and a hose length of 100 feet.
(3) Based on data from one of the sampled vessels: 2,700 cubic feet per tank, 3 tanks (229,461.75 liters of tanks space), holds 325,000 lbs of salmon (163,798 liters of fish assuming density of fish is 0.9 kg/L). 163,798 liters of fish/229,461.75 liters of tanks space = 70% of fish. Assume remaining is hold water.
(4) Based on sampling team observation in the field.
(5) WaterSense Showerhead Factoids, Draft Date 7/27/09.

Table 4.3.3. Vessel Flow Rates

Vessel Class	Vessel Subclass	Discharge	Flow Discharged to Harbor per Vessel (m^3/day) [1]
Fire Boat	NA	Deck Wash	0.0100
Fire Boat	NA	Engine Effluent	36.3
Fire Boat	NA	Fire Main Effluent	0.00 [2]
Fire Boat	NA	Generator Effluent	1.80
Fishing	Gillnetter	Engine Effluent	14.9
Fishing	Gillnetter	Fish Hold Effluent	0.800
Fishing	Lobster Boat	Fish Hold Effluent	2.83
Fishing	Longliner	Bilgewater	0.450
Fishing	Longliner	Fish Hold Effluent	2.83
Fishing	Longliner	Fish Hold Cleaning Effluent	0.00 [2]
Fishing	Purse Seiner	Engine Effluent	16.6
Fishing	Purse Seiner	Fish Hold Effluent	16.3
Fishing	Purse Seiner	Fish Hold Cleaning Effluent	1.07
Fishing	Purse Seiner	Generator Effluent	1.41
Fishing	Shrimper	Bilgewater	2.84
Fishing	Shrimper	Deck Wash	0.344
Fishing	Shrimper	Fish Hold Effluent	1.25
Fishing	Shrimper	Graywater	0.00 [2]
Fishing	Tender Vessel	Fish Hold Effluent	19.3
Fishing	Tender Vessel	Fish Hold Cleaning Effluent	0.660
Fishing	Trawler	Deck Wash	0.344
Fishing	Trawler	Fish Hold Effluent	1.25
Fishing	Trawler	Fish Hold Clean	0.220
Fishing	Troller	Deck Wash	0.470
Fishing	Troller	Fish Hold Effluent	3.04
Fishing	Troller	Fish Hold Cleaning Effluent	0.660
Research	NA	Engine Effluent	0.0900
Supply Boat	NA	Deck Wash	0.0300
Tour Boat	NA	Bilgewater	0.0400
Tour Boat	NA	Deck Wash	0.140
Tour Boat	NA	Engine Effluent	42.2
Tour Boat	NA	Fire Main Effluent	0.00 [2]
Tour Boat	NA	Generator Effluent	3.82
Tow/Salvage	NA	Bilgewater	1.39
Tow/Salvage	NA	Deck Wash	0.0240
Tow/Salvage	NA	Engine Effluent	0.952
Tugboat	NA	Deck Wash	0.0978
Tugboat	NA	Fire Main Effluent	0.00 [2]
Tugboat	NA	Graywater	0.478
Tugboat	NA	Shaft Water	0.0100

Table 4.3.3. Vessel Flow Rates

Vessel Class	Vessel Subclass	Discharge	Flow Discharged to Harbor per Vessel (m^3/day) [1]
Water Taxi	NA	Bilgewater	0.130
Water Taxi	NA	Deck Wash	0.0650
Water Taxi	NA	Engine Effluent	39.8
Water Taxi	NA	Generator Effluent	9.08
Water Taxi	NA	Graywater	0.280

NA – Not applicable.
(1) EPA estimated discharge flow rates for each vessel class based on data and field observations from EPA's vessel sampling program, as well as information from secondary data sources. EPA assumes that discharges not listed for a given vessel class are either not generated by a given vessel class or are discharged outside of the hypothetical harbor area.
(2) These waste streams are all discharged in the harbor; however, the relatively small volume and infrequency of the discharge results in an insignificant daily discharge volume.

4.3.3 Number of Vessels Present in the Harbor

The total number of vessels present in any given harbor and the distribution of vessels among the different vessel classes operating in that harbor vary significantly across the United States. The number and distribution of vessels among the different classes depend on factors such as the regional economic base (e.g., fishing versus recreation), size of the city supporting the harbor, and geographic location (e.g., Alaska versus Gulf of Mexico). To represent the variety of vessel combinations potentially present in a harbor, EPA developed the following three vessel population scenarios for the model:

- Scenario 1: Fishing Harbor - A harbor where fishing is the primary economic driver in the region, and fishing vessels represent the majority of vessels present in the harbor[5].

- Scenario 2: Large Metropolitan Harbor - A harbor where there are nonrecreational study vessels associated with a large metropolitan city that would require a greater number of support vessels such as supply boats, tow/salvage vessels, and tugboats. In addition, EPA assumed that there would be a higher level of vessel activity within the hypothetical harbor compared to the activity assumed for Scenarios 1 and 3. Note that this screening analysis does not include large non study vessels such as container ships, tankers, bulk carriers, or other larger vessels, which would be present in almost any large port[6].

- Scenario 3: Recreational Harbor – A harbor where the primary economic driver is the tourist or recreation industry. Although recreational vessels are not study vessels, EPA assumed that a recreational harbor would have a high concentration of nonrecreational support vessels such as tow/salvage, tour boats, and water taxis associated with the regional recreational and tourist industry. However, as noted previously, this analysis does not consider discharges from non study vessels and other sources.

EPA used data from the MISLE database maintained by the U.S. Coast Guard to develop the number of vessels present in the hypothetical harbors for the three scenarios and the distribution among the different vessel classes. The MISLE database includes a wide range of information regarding vessel and facility characteristics, accidents, marine pollution incidents, and other pertinent information tracked by the U.S. Coast Guard from investigation and

[5] Charter fishing vessels are not modeled as part of this analysis. Charter fishing vessels are generally either manufactured or used primarily for pleasure, or leased, rented, or chartered to a person for the pleasure of that person. Many are not inspected by the US Coast Guard. These vessels are exempted from NPDES permitting requirements by the Clean Boating Act (P.L. 110-288). Other charter fishing vessels are inspected by the US Coast Guard. These inspected, non-recreational vessels are not exempted from NPDES by the Clean Boating Act, and are study vessels only if they are less than 79 feet. As a general matter, therefore, EPA anticipates that a significant portion of charter fishing vessels are not study vessels.

[6] Due to time and resource constraints, EPA did not sample these large vessels for this study. Therefore, EPA did not calculate loadings from these larger vessels for this screening analysis.

inspection activity. While MISLE represents the most comprehensive national dataset currently available, it may not capture the entire universe of study vessels that operate in U.S. waters (see Chapter 1 of this report for further discussion about the vessel universe in this study and the MISLE database).

EPA identified and compiled hailing port and vessel class distribution data on the top 20 hailing ports cited in the MISLE database. Based on the identified harbors, EPA selected representative harbors for each vessel population scenario to develop the vessel distributions in the model (see Table 4.3.4).

Table 4.3.4. Vessel Population Scenario Representative Harbors Based on the Top 20 Hailing Ports Cited in the MISLE Database

Top 20 Hailing Ports Cited in MISLE	Vessel Population Scenario 1 Fishing Harbor	Vessel Population Scenario 2 Large Metropolitan Harbor	Vessel Population Scenario 3 Recreational Harbor
Boston, MA		X	
Cordova, AK	X		
Gloucester, MA	X		
Homer, AK	X		
Houma, LA			X
Houston, TX	X		X
Juneau, AK	X		
Ketchikan, AK	X		
Key West, FL			X
Kodiak, AK	X		
Miami, FL		X	X
New Orleans, LA	X	X	X
New York, NY		X	X
Norfolk, VA			X
Petersburg, AK	X		
Portland, OR	X		X
San Diego, CA		X	X
San Francisco, CA			X
Seattle, WA	X		X
Sitka, AK	X		

For each representative harbor, EPA calculated the percentages of fishing vessels and non-fishing study vessels reported in the MISLE database (see Table 4.3.5, Table 4.3.6, and Table 4.3.7). EPA averaged the percentages of fishing and non-fishing vessels to develop the overall proportion of these vessel types for each vessel population scenario.

Table 4.3.5. Percentage of Study Vessels Present in Representative Fishing Harbor

Hailing Port	Percentage of Fishing Vessels	Percentage of Non-fishing Study vessels
New Orleans, LA	26%	74%
Seattle, WA	69%	31%
Houston, TX	56%	44%
Juneau, AK	82%	18%
Houma, LA	39%	61%
Cordova, AK	94%	6%
Homer, AK	82%	18%
Sitka, AK	76%	24%
Kodiak, AK	91%	9%
Portland, OR	51%	49%
Ketchikan, AK	62%	38%
Gloucester, MA	84%	16%
Petersburg, AK	93%	7%
Average	**70%**	**30%**

Source: MISLE database.

Table 4.3.6. Percentage of Study Vessels Present in Representative Large Metropolitan Harbor

Hailing Port	Percentage of Fishing Vessels	Percentage of Non-fishing Study vessels
New Orleans, LA	26%	74%
New York, NY	21%	79%
Miami, FL	43%	57%
Boston, MA	55%	45%
San Diego, CA	37%	63%
Average	**36%**	**64%**

Source: MISLE database.

Table 4.3.7. Percent of Study Vessels Present in Representative Recreational Harbor

Hailing Port	Percent of Fishing Vessels	Percent of Non-fishing Study vessels
New Orleans, LA	26%	74%
Seattle, WA	69%	31%
New York, NY	21%	79%
Houston, TX	56%	44%
San Francisco, CA	64%	36%
Miami, FL	43%	57%
Norfolk, VA	28%	72%
Houma, LA	39%	61%
San Diego, CA	37%	63%
Portland, OR	51%	49%
Key West, FL	47%	53%
Average	**44%**	**56%**

Source: MISLE database.

EPA established the total number of vessels present in each vessel population scenario based on:

- Field observations from EPA's vessel sampling program.
- Total vessel population data for the top 20 hailing ports as reported in the MISLE database.
- An assumption that the hypothetical harbor is representative of up to 10 miles of shoreline.
- An assumption that the vessel distributions reflect vessel populations during peak activity for each scenario (i.e., summer season during peak fishing, recreational, and tourist activity).

Based on these assumptions, EPA selected a total vessel population of 175 vessels for Scenarios 1 and 3 and 300 vessels for Scenario 2 (see Table 4.3.8). Table 4.3.8 presents the distribution of vessels among the different vessel classes for each vessel population scenario developed using the vessel ratios discussed above, assumptions on the total vessel population, field observations, and best professional judgment.

Table 4.3.8. Vessel Population Scenarios

Vessel Class	Vessel Subclass	Vessel Population Scenario 1 Fishing Harbor	Vessel Population Scenario 2 Metropolitan Harbor	Vessel Population Scenario 3 Recreational Harbor
Fire Boat	NA	1	5	1
Fishing	Gillnetter	12	10	9
Fishing	Lobster Boat	12	10	9
Fishing	Longliner	24	16	15
Fishing	Purse Seiner	12	10	9
Fishing	Shrimper	10	8	5
Fishing	Tender Vessel	20	10	9
Fishing	Trawler	20	16	13
Fishing	Troller	12	10	9
Research	NA	2	10	8
Supply Boat	NA	12	55	10
Tour Boat	NA	10	20	24
Tow/Salvage	NA	6	40	20
Tugboat	NA	12	60	10
Water Taxi	NA	10	20	24
Total Number of Vessels		**175** [1]	**300** [2]	**175** [3]

NA – Not applicable.
(1) Fishing harbor - percentage of fishing vessels is 70%, percentage of non-fishing vessels is 30%.
(2) Large metropolitan harbor - percentage of fishing vessels is 30%, percentage of non-fishing vessels is 70%.
(3) Recreational harbor - percentage of fishing vessels is 45%, percentage of non-fishing vessels is 55%.

4.3.4 Percentage of Vessels Discharging in the Harbor

In addition to the number of vessels present in the harbor, EPA also established the percentage of vessels within each vessel class and discharge type that discharge into the harbor. The purpose of this is to account for the fact that not all vessels within a vessel class discharge all waste streams. EPA developed and selected the percentage of vessels discharging to the harbor (see Table 4.3.9) based on interview responses and data collected during EPA's vessel sampling program. EPA assumed all sampled vessels generate all discharges unless otherwise noted by the vessel operators as follows:

- Vessel does not have the system or process responsible for the discharge (e.g., the vessel does not generate graywater as it does not have sinks, showers, or washing machines).
- System has no discharge (e.g., vessel propulsion and generator engines are keel-cooled).
- Vessel typically discharges outside U.S. waters (e.g., fishing vessel washes decks after each catch at fishing grounds greater than 12 nautical miles from shore).

Based on these criteria, EPA calculated the percentage of vessels ($P_{y,z}$) in each vessel class that discharge each discharge type into the harbor using the following equation:

$P_{y,z} = Sample\ N_{y,z} / Sample\ N_z$ Equation 4-6

Where:

$P_{y,z}$ = Percentage of vessels in vessel class z discharging discharge y

$Sample\ N_{y,z}$ = Number of vessels in vessel class z discharging discharge y from EPA's vessel sampling program

$Sample\ N_z$ = Number of vessels from vessel class z from EPA's vessel sampling program

Appendix G includes the field data and assumptions used to develop the percentage of vessels input parameter ($P_{y,z}$) for each vessel class and discharge stream.

Table 4.3.9. Percentage of Vessels Discharging in the Harbor

Vessel Class	Vessel Subclass	Discharge	Percentage of Vessels Discharging Flow in Harbor [1]
Fire Boat	NA	Deck Wash	100%
Fire Boat	NA	Engine Effluent	100%
Fire Boat	NA	Fire Main Effluent	100%
Fire Boat	NA	Generator Effluent	100%
Fishing	Gillnetter	Engine Effluent	80%
Fishing	Gillnetter	Fish Hold Effluent	80%
Fishing	Lobster Boat	Fish Hold Effluent	100%
Fishing	Longliner	Bilgewater	33%
Fishing	Longliner	Fish Hold Effluent	100%
Fishing	Longliner	Fish Hold Cleaning Effluent	100%
Fishing	Purse Seiner	Engine Effluent	40%
Fishing	Purse Seiner	Fish Hold Effluent	100%
Fishing	Purse Seiner	Fish Hold Cleaning Effluent	100%
Fishing	Purse Seiner	Generator Effluent	40%
Fishing	Shrimper	Bilgewater	50%
Fishing	Shrimper	Deck Wash	80%
Fishing	Shrimper	Fish Hold Effluent	80%
Fishing	Shrimper	Graywater	100%
Fishing	Tender Vessel	Fish Hold Effluent	100%
Fishing	Tender Vessel	Fish Hold Cleaning Effluent	67%
Fishing	Trawler	Deck Wash	80%
Fishing	Trawler	Fish Hold Effluent	80%
Fishing	Trawler	Fish Hold Clean Effluent	40%
Fishing	Troller	Deck Wash	17%
Fishing	Troller	Fish Hold Effluent	100%
Fishing	Troller	Fish Hold Cleaning Effluent	33%

Table 4.3.9. Percentage of Vessels Discharging in the Harbor

Vessel Class	Vessel Subclass	Discharge	Percentage of Vessels Discharging Flow in Harbor [1]
Research	NA	Engine Effluent	100%
Supply Boat	NA	Deck Wash	100%
Tour Boat	NA	Bilgewater	67%
Tour Boat	NA	Deck Wash	67%
Tour Boat	NA	Engine Effluent	100%
Tour Boat	NA	Fire Main Effluent	100%
Tour Boat	NA	Generator Effluent	67%
Tow/Salvage	NA	Bilgewater	33%
Tow/Salvage	NA	Deck Wash	100%
Tow/Salvage	NA	Engine Effluent	83%
Tugboat	NA	Deck Wash	100%
Tugboat	NA	Fire Main Effluent	100%
Tugboat	NA	Graywater	67%
Tugboat	NA	Shaft Water	89%
Water Taxi	NA	Bilgewater	75%
Water Taxi	NA	Deck Wash	100%
Water Taxi	NA	Engine Effluent	100%
Water Taxi	NA	Generator Effluent	25%
Water Taxi	NA	Graywater	25%

NA – Not applicable.
(1) The percentages of vessels discharging to the harbor were determined based on field observations of sampled vessels. As a conservative estimate, it was assumed that 100% of vessels in sampled vessel classes with no information available discharge in the harbor.

4.3.5 Vessel Discharge Loading Rates

EPA calculated the vessel class-specific loading rates for each analyte ($W_{e,z}$) using Equation 4-1 for each of the three vessel population scenarios described in Section 4.3.3. EPA then calculated the total analyte-specific load rates (W_e) for each vessel population scenario using Equation 4-2. Appendix G presents the total analyte-specific loading rates for each of the three vessel population scenarios represented in the model (i.e., fishing harbor, large metropolitan harbor, and recreational harbor).

4.3.6 Dissolved Copper Loading Rates from Antifouling Paints

In addition to the loading rates calculated based on EPA's vessel sampling program data, EPA also considered the additional dissolved copper load to receiving waters associated with antifouling paints used on vessel hulls. As described in Chapter 3, antifouling systems (AFSs) are designed to release biocide over time to retard growth and maintain a smooth underwater surface (Schiff et al., 2003). Copper oxide is the most common biocide added to AFSs to prevent biofouling organisms from attaching to the hull. Numerous studies have investigated the leaching rate of copper from both passive leaching and underwater hull cleaning (Thomas et al., 1999; Zirino and Seligman, 2002; Valkirs et al., 2003; Schiff et al., 2003). Based on estimates produced in these studies, EPA selected a dissolved copper leaching rate of 8.2 $\mu g/cm^2/day$ to estimate the additional dissolved copper load to the harbor from vessel AFSs. EPA estimated the average vessel length for each vessel class based on information available in the MISLE database and field observations from EPA's vessel sampling program (Table 4.3.10). EPA assumed that the beam of the vessel beam (i.e., width) was equal to approximately one-third its length and used Equation 4-7 (Interlux, 1999) to estimate the hull surface area for each vessel class:

$$A_z = L_z * (L_z/3) * 0.85 \qquad \text{Equation 4-7}$$

Where:

A_z = Hull surface area for individual vessels in vessel class z (area)
L_z = Average length of vessels in vessel class z (distance)

Table 4.3.10. Estimated Average Vessel Length by Vessel Class

Vessel Class	Vessel Subclass	Vessel Length (feet) [1]
Fire Boat	NA	50
Fishing	Gillnetter	35
Fishing	Lobster Boat	35
Fishing	Longliner	35
Fishing	Purse Seiner	50
Fishing	Shrimper	50
Fishing	Tender Vessel	100
Fishing	Trawler	50
Fishing	Troller	35
Research	NA	40
Supply Boat	NA	50
Tour Boat	NA	50
Tow/Salvage	NA	40
Tugboat	NA	79
Water Taxi	NA	79

NA – Not applicable.
(1) - EPA estimated the average vessel length for each vessel class based on information available in the MISLE database and field observations during EPA's vessel sampling program.

EPA calculated the dissolved copper loading rate from AFSs for each vessel population scenario using Equation 4-8, and then added these loadings to the dissolved copper loading rates calculated in Section 4.3.5 for the other vessel discharges to determine the total dissolved copper load introduced into the harbor for each loading scenario[7]. EPA calculated that AFSs contribute approximately 2.79 lbs/day of dissolved copper under Vessel Population Scenario 1 (fishing harbor), 4.86 lbs/day under Vessel Population Scenario 2 (large metropolitan harbor), and 2.63 lbs/day under Vessel Population Scenario 3 (recreational harbor[8]). Appendix G presents the total dissolved copper loading rates represented in the model.

$$AFC\ W_{copper} = \Sigma\ N_z * A_z * 8.2\ \mu g/cm^2/day \qquad \text{Equation 4-8}$$

Where:

$AFS\ W_{copper}$	=	AFS discharge loading rate for dissolved copper (mass/time)
N_z	=	Number of vessels in vessel class z present in the harbor
A_z	=	Hull surface area for individual vessels in vessel class z (area)

4.4 HYPOTHETICAL HARBOR

Given the wide variety of coastal harbor environments potentially impacted by study vessel discharges, EPA developed several hypothetical harbors for the vessel discharge environmental assessment to represent a range of environmental conditions that could potentially be impacted. To develop input values that represented realistic environmental conditions, EPA identified and collected environmental data on eight harbors (Table 4.4.1) that represented a geographically and environmentally diverse group of water bodies, had the potential for a high density of study vessels, and received freshwater inflow from a major river system.

Table 4.4.1. Harbors Selected for Model Input Parameter Development

Harbor Name	City Name	State	River Name
Cohasset Harbor	Boston	Massachusetts	Gulf River
Dorchester Bay	Boston	Massachusetts	Neponset River
Auke Bay	Juneau	Alaska	Mendenhall River
Biscayne Bay	Miami	Florida	Miami River
Mobile Bay	Mobile	Alabama	Tensaw, Blakeley, and Mobile River
Yaquina Bay	Newport	Oregon	Yaquina River
Craford Bay	Norfolk	Virginia	Eastern and Southern Branch Elizabeth River
Eastern Channel	Sitka	Alaska	Indian River

The "fraction of freshwater model" requires the following four input parameters to define the water body characteristics:

[7] Note that some hull cleaning methods can release a plume of antifouling paint, which contains copper in particulate form, in the water. The particulate copper can settle into the sediments and over time reenter the water body in the dissolved form. EPA did not include the potential dissolved copper load from particulate copper resulting from hull cleaning.

[8] As noted above, these loading rates do not include the loading from nonstudy vessels.

- Seaward boundary salinity at the mouth of the harbor (S_s)
- Salinity at location x in the harbor (S_x)
- Volume of the harbor (V)
- Inflow of freshwater to the harbor (Q_{fw})

EPA collected data on the four input parameters for the harbors listed in Table 4.4.1 and calculated a flushing time using Equation 4-4 in Section 4.2.3. Appendix G presents the environmental data identified by EPA for each harbor listed in Table 4.4.1. EPA selected the input parameters for the hypothetical harbors' salinity, volume, and river flow based on the environmental data collected for the harbors with the minimum and maximum flushing times (Table 4.4.2). EPA assumed an average ocean salinity of 35 PSU for the salinity at the seaward boundary of the hypothetical harbor.

Table 4.4.2. Hypothetical Harbor Input Parameters

Model Parameter	Model Input Value	Units
Harbor Salinity (S_x) Minimum	26.1	PSU
Harbor Salinity (S_x) Maximum	31	PSU
Ocean Salinity (S_s)	35	PSU
Harbor Volume (V) Minimum	3,090,000	m^3
Harbor Volume (V) Maximum	38,500,000	m^3
River Flow (Q_{fw}) Minimum	352,000	m^3/day
River Flow (Q_{fw}) Maximum	2,900,000	m^3/day

Using the input parameters in Table 4.4.2, EPA developed eight hypothetical harbors for the vessel discharge environmental assessment (see Table 4.4.3). For each harbor scenario, EPA calculated the fraction of freshwater (f_x) and flushing time (t) using Equations 4-3 and 4-4 in Sections 4.2.2 and 4.2.3, respectively. Flushing times for the hypothetical harbors ranged from less than a day (0.122 days or 2.9 hours) to 27.8 days.

Table 4.4.3. Hypothetical Harbor Scenarios

Hypothetical Harbor Scenarios	Harbor Salinity (S_x)	Ocean Salinity (S_s)	Harbor Volume (V)	River Flow (Q_{fw})	f_x	Flushing Time (Days)
Harbor Scenario 1	26.1 PSU S_x Min	35 PSU	3,090,000 m^3 V Min	352,000 m^3/day Q_{fw} Min	0.254	2.23
Harbor Scenario 2	26.1 PSU S_x Min	35 PSU	3,090,000 m^3 V Min	2,900,000 m^3/day Q_{fw} Max	0.254	0.271
Harbor Scenario 3	26.1 PSU S_x Min	35 PSU	38,500,000 m^3 V Max	352,000 m^3/day Q_{fw} Min	0.254	27.8
Harbor Scenario 4	26.1 PSU S_x Min	35 PSU	38,500,000 m^3 V Max	2,900,000 m^3/day Q_{fw} Max	0.254	3.38
Harbor Scenario 5	31 PSU S_x Max	35 PSU	3,090,000 m^3 V Min	352,000 m^3/day Q_{fw} Min	0.114	1
Harbor Scenario 6	31 PSU S_x Max	35 PSU	3,090,000 m^3 V Min	2,900,000 m^3/day Q_{fw} Max	0.114	0.122
Harbor Scenario 7	31 PSU S_x Max	35 PSU	38,500,000 m^3 V Max	352,000 m^3/day Q_{fw} Min	0.114	12.5
Harbor Scenario 8	31 PSU S_x Max	35 PSU	38,500,000 m^3 V Max	2,900,000 m^3/day Q_{fw} Max	0.114	1.52

4.5 MODEL SCENARIOS

EPA developed a total of 24 model scenarios (see Table 4.5.1) for the screening-level analysis based on the three vessel population scenarios and the eight hypothetical harbors discussed in Sections 4.3.3 and 4.4, respectively. EPA calculated the estimated harbor dilution for each model scenario using the following equation:

$$D_x = (V/t)/\Sigma(Q_{y,z} * N_{y,z} * P_{y,z}) \quad \text{Equation 4-9}$$

Where:

D_x = Harbor dilution at location x

V = Volume of model harbor

t = Model harbor flushing time

$Q_{y,z}$ = Flow rate for discharge y from vessel class z (volume/time)

$N_{y,z}$ = Number of vessels in vessel class z discharging discharge y

$P_{y,z}$ = Percent of vessels in vessel class z discharging discharge y

Table 4.5.1. Fraction of Freshwater Model Scenarios

Model Scenario	Total Loading Rate (W_e) Scenario	Hypothetical Harbor Scenario	Dilution (D_x)
Model Scenario 1	Vessels Population Scenario 1 Fishing Harbor	Harbor Scenario 1	705
Model Scenario 2	Vessels Population Scenario 1 Fishing Harbor	Harbor Scenario 2	5,810
Model Scenario 3	Vessels Population Scenario 1 Fishing Harbor	Harbor Scenario 3	705
Model Scenario 4	Vessels Population Scenario 1 Fishing Harbor	Harbor Scenario 4	5,810
Model Scenario 5	Vessels Population Scenario 1 Fishing Harbor	Harbor Scenario 5	1,570
Model Scenario 6	Vessels Population Scenario 1 Fishing Harbor	Harbor Scenario 6	12,900
Model Scenario 7	Vessels Population Scenario 1 Fishing Harbor	Harbor Scenario 7	1,570
Model Scenario 8	Vessels Population Scenario 1 Fishing Harbor	Harbor Scenario 8	12,900
Model Scenario 9	Vessels Population Scenario 2 Metropolitan Harbor	Harbor Scenario 1	506
Model Scenario 10	Vessels Population Scenario 2 Metropolitan Harbor	Harbor Scenario 2	4,170
Model Scenario 11	Vessels Population Scenario 2 Metropolitan Harbor	Harbor Scenario 3	506
Model Scenario 12	Vessels Population Scenario 2 Metropolitan Harbor	Harbor Scenario 4	4,170
Model Scenario 13	Vessels Population Scenario 2 Metropolitan Harbor	Harbor Scenario 5	1,130
Model Scenario 14	Vessels Population Scenario 2 Metropolitan Harbor	Harbor Scenario 6	9,280
Model Scenario 15	Vessels Population Scenario 2 Metropolitan Harbor	Harbor Scenario 7	1,130
Model Scenario 16	Vessels Population Scenario 2 Metropolitan Harbor	Harbor Scenario 8	9,280
Model Scenario 17	Vessels Population Scenario 3 Recreational Harbor	Harbor Scenario 1	494
Model Scenario 18	Vessels Population Scenario 3 Recreational Harbor	Harbor Scenario 2	4,070
Model Scenario 19	Vessels Population Scenario 3 Recreational Harbor	Harbor Scenario 3	494
Model Scenario 20	Vessels Population Scenario 3 Recreational Harbor	Harbor Scenario 4	4,070
Model Scenario 21	Vessels Population Scenario 3 Recreational Harbor	Harbor Scenario 5	1,100
Model Scenario 22	Vessels Population Scenario 3 Recreational Harbor	Harbor Scenario 6	9,050
Model Scenario 23	Vessels Population Scenario 3 Recreational Harbor	Harbor Scenario 7	1,100
Model Scenario 24	Vessels Population Scenario 3 Recreational Harbor	Harbor Scenario 8	9,050

As shown in Table 4.5.1, there are duplicate dilution factor values for different model scenarios (e.g., Model Scenarios 1 and 3 both have a dilution factor of 705). Hence, there are effectively 12 unique model scenarios and not 24 presented in this screening-level analysis. The duplicate dilution factors are an artifact of EPA's decision to calculate dilution factors and instantaneous harbor concentrations using all combinations of the input parameters in Table 4.4.2. In calculating the dilution factor, the volume of the harbor (V) cancels out of the dilution equation (Equation 4-9) and is not a consideration (see below).

$$D_x = (V/t)/\Sigma(Q_{y,z} * N_{y,z} * P_{y,z})$$

Where:

(V/t) = $(V/(V*f_x/Q_{fw})$

$\Sigma(Q_{y,z} * N_{y,z} * P_{y,z})$ = Total discharge flow from all vessels

EPA used three total discharge flows ($\Sigma(Q_{y,z} * N_{y,z} * P_{y,z})$ (i.e., vessel flows in a fishing harbor, large metropolitan harbor, and recreational harbor) and four different volume-to-flushing-time (V/t) ratios (i.e., assumed two f_x values in the model and two Q_{fw} values) in the model. Section 4.6 discusses the results from the 12 unique model scenarios and presents the results of the duplicate scenarios as one result (i.e., harbor concentrations from Model Scenarios 1 and 3).

4.6 MODEL RESULTS

EPA calculated the instantaneous concentration (C_x) in the hypothetical harbor using Equation 4-5 presented in Section 4.2.4 for each of the 12 model scenarios defined in Table 4.5.1. Appendix G presents the concentrations for all model scenarios for each vessel population scenario. EPA compared the instantaneous concentrations in the hypothetical harbor with the NRWQC to evaluate the potential for the cumulative effect of study vessel incidental discharges to impact aquatic life or human health. EPA determined that none of the modeled concentrations in the hypothetical harbor for the 12 scenarios exceeded an aquatic life or human health NRWQC.

4.6.1 Dilution Factor Analysis

The model scenario dilutions factors calculated for the 12 unique scenarios ranged from 494 to 12,900. EPA performed a sensitivity analysis to determine the dilution factor at which point NRWQC would be exceeded. EPA calculated the "tipping point" dilution in the hypothetical harbor where the instantaneous concentration in the harbor would equal the most stringent NRWQC for aquatic life or human health using the three vessel population scenario loading rates discussed in Section 4.3.5. Table 4.6.1 presents the tipping point dilution factors for the top 10 analytes with the highest dilution factor requirements to avoid exceeding an NRWQC. Based on the results of the dilution analysis, a harbor dilution factor of greater than 358 is required to avoid exceeding any NRWQC for aquatic life or human health, which is below the range of calculated model scenario dilution factors (i.e., 494 to 12,900). This sensitivity analysis also demonstrates that dissolved copper and total arsenic represent the most significant environmental risk from study vessels incidental discharges. These two analytes have relatively stringent range of dilution requirements depending on the vessel population scenario selected to avoid exceeding a NRWQC (i.e., dilution factors of greater than 144 to 266 for dissolved copper and 284 to 358 for total arsenic) and represent the highest dilution requirements for all the analytes detected in vessel discharges. Following dissolved copper, the required dilution factors drop off significantly with a dilution of greater than 33.7 required to avoid exceeding all other NRWQC with most of the remaining dilution factors below one.

Table 4.6.1. "Tipping Point" Dilution Factors for Harbor Instantaneous Concentration to Equal the NRQWC Based on Vessel Population Scenario Loading Rates [1]

Class	Analyte	Vessel Scenario 1 Fishing Harbor Dilution (D_x)	Vessel Scenario 2 Metropolitan Harbor Dilution (D_x)	Vessel Scenario 3 Recreational Harbor Dilution (D_x)
Metals	Arsenic, Total [2]	358	331	284
Metals	Copper, Dissolved	214	266	144
Metals	Arsenic, Dissolved [2]	31.4	33.7	29.6
Classicals	Total Residual Chlorine	12.4	16.2	12.2
Metals	Aluminum, Total	6.77	5.15	4.83
Classicals	Sulfide	1.75	2.36	1.65
Metals	Selenium, Total [2]	1.13	1.46	1.52
VOC	Benzene	0.756	1.57	1.34
Metals	Manganese, Total	0.684	0.983	1.04

(1) Table includes only those analytes that required a dilution factor of greater than one to avoid exceeding a NRWQC.
(2) EPA suspects a limited number of the samples analyzed for selenium (and even fewer for arsenic) for bilgewater, packing gland effluent, propulsion engine effluent, graywater and deck washdown water may have elevated measured concentrations due to positive interference. Despite these limited instances of interference, EPA believes the fish hold concentrations reasonably represent true effluent concentrations for the discharge (see discussion in Sections 3.1.3 and 3.2.4.1 for further information). EPA considered these interferences when interpreting the potential for vessel discharges to pose a risk to human health, aquatic life, or the environment and determined that such cationic interference does not influence the major findings presented in the modeling analysis.

4.6.2 Supplemental Model Run in Response to Comments

In response to public comments submitted for the draft version of this report, EPA performed a supplemental model run using revised values based on information submitted by commenters to assess the impacts of these alternative values on the model results. EPA adjusted the model assumptions presented in Table 4.6.2 and recalculated the associated discharge flows and loads. EPA observed no significant change in model results based on the revised values. Table 4.6.3 presents the revised "tipping point" dilution factors for the supplemental model run.

Table 4.6.2. Revised Model Assumptions

Vessel Class	Vessel Subclass	Discharge	Old Assumption	New Assumption
Fishing	Gillnetter	Fish Hold	Offloads daily	Offloads once per five days
Fishing	Longliner	Fish Hold	Offloads once per two days	Offloads once per five days
Fishing	Toller	Fish Hold Clean	Offloads daily	Offloads once per seven days
Fishing	Toller	Fish Hold	Offloads daily	Offloads once per seven days
Fishing	Toller	Fish Hold	840 ft^3 fish hold	595 ft^3 fish hold
Fishing	Toller	Fish Hold	5.5 tons of ice per offload	2 tons of ice per offload
Fishing	Toller	Deck Wash	125 gallons per deck wash	50 gallons per deck wash
Fishing	Shrimping	Bilge Water	150 gallons per minute bilge pump rate	20 gallons per minute bilge pump rate
Tour Boat	NA	Bilge Water	14.3 gallons per day	5 gallons per day

Table 4.6.3. Supplemental Model Run "Tipping Point" Dilution Factors for Harbor Instantaneous Concentration to Equal the NRQWC Based on Vessel Population Scenario Loading Rates [1]

Class	Analyte	Vessel Scenario 1 Fishing Harbor Dilution (D_x)	Vessel Scenario 2 Metropolitan Harbor Dilution (D_x)	Vessel Scenario 3 Recreational Harbor Dilution (D_x)
Metals	Arsenic, Total [2]	349	325	279
Metals	Copper, Dissolved [3]	225	273	147
Metals	Arsenic, Dissolved [2]	31.1	33.6	29.5
Classicals	Total Residual Chlorine	12.4	16.2	12.1
Metals	Aluminum, Total	6.77	5.10	4.79
Classicals	Sulfide	1.68	2.33	1.60
Metals	Selenium, Total [2]	1.03	1.42	1.50
VOC	Benzene[3]	0.790	1.61	1.37
Metals	Manganese, Total [3]	0.696	0.997	1.05

(1) Table includes only those analytes that required a dilution factor of greater than one to avoid exceeding a NRWQC.
(2) EPA suspects a limited number of the samples analyzed for selenium (and even fewer for arsenic) for bilgewater, packing gland effluent, propulsion engine effluent, graywater and deck washdown water may have elevated measured concentrations due to positive interference. Despite these limited instances of interference, EPA believes the fish hold concentrations reasonably represent true effluent concentrations for the discharge (see discussion in Sections 3.1.3 and 3.2.4.1 for further information). EPA considered these interferences when interpreting the potential for vessel discharges to pose a risk to human health, aquatic life, or the environment and determined that such cationic interference does not influence the major findings presented in the modeling analysis.
(3) The revised model assumptions (see Table 4.6.2) did not significantly impact the total loads for this analyte; however, these assumptions lowered the total discharge volume from these vessels. Therefore, the dilution factors for the supplemental model run for this analyte are higher than the original model run due to the same mass loading rate being divided by a smaller total discharge flow.

4.6.3 Loading Rate Analysis

EPA compared the three analyte-specific loading rates used in the model with other known loading rates to provide perspective on their magnitude and on their relative contribution to the possible impairment of receiving waters (see Table 4.6.2 and Table 4.6.3). EPA selected the following loading sources for comparison:

- Loads From Publicly Owned Treatment Works (POTW)
- Dissolved copper loads discharged to the Shelter Island Yacht Basin
- Estimated metal loading rates from urban stormwater

EPA generated estimates for hypothetical medium-sized sewage treatment facilities with a discharge rate of 10 million gallons per day (MGD). These estimates were derived from the

National Research Council's 1993 report "Managing Wastewater in Urban Areas". EPA calculated loadings by multiplying an effluent volume of 10 MGD times the low and high effluent concentrations for selected parameters using four types of wastewater treatment (chemically-enhanced primary plus biological treatment, primary or chemically enhanced primary plus nutrient removal, primary or chemically enhanced primary plus nutrient removal plus gravity filtration, or primary or chemically enhanced primary plus nutrient removal plus high lime plus filtration)[9]. Values presented in Table 4.6.2 present the lowest and highest derived loadings for these medium systems. EPA determined that the nutrient loads from the 175 to 300 study vessels were comparable to the low end estimates for Ammonia as Nitrogen and total phosphorus, but notably lower than those from the high end treated effluent estimates from sewage treatment facilities. As noted above, the model nutrient loadings from study vessels do not include sewage discharges (which is likely a source of nutrients from these vessels)[10], whereas these data are from POTW effluent, which has a significant sewage component. Table 4.6.2 shows that a medium sewage treatment facility discharges a higher volume of metals than these 175 to 300 study vessels. Finally, these study vessels discharge comparable levels of BOD; though sewage treatment facilities are discharging a larger volume of effluent, they remove significant quantities of BOD from the effluent. On the other hand, study vessels' incidental discharges are untreated waste, some of which has notably high BOD concentrations (e.g., fish hold effluent).

EPA also obtained nutrient loading estimates from a sewage treatment facility with advanced nutrient removal capabilities to provide real world example nutrient loadings that may be associated with POTW discharges (Albert, 2007). This facility discharges approximately 40 to 50 MGD. EPA determined that the nutrient loads (i.e., ammonia as nitrogen, nitrate/nitrite as nitrogen, total Kjeldahl nitrogen, and total phosphorus) from the 175 to 300 study vessels used to establish the vessel loads in the screening-level analysis were notably lower than the nutrient loads from this sewage treatment facility. It is important to note that these model nutrient loads do not include nutrient contributions from vessel sewage discharges (possibly a significant source of nutrients), as sewage discharges are excluded from the scope of P.L. 110-299.

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[9] A number of systems exist which are both smaller and larger than 10 MGD; for example, the Blue Plains POTW in Washington DC is the largest advanced wastewater treatment system in the word and discharges an average of approximately 330 MGD. The wastewater treatment facilities in nearby Arlington County discharge less than 40 MGD. In comparison, the sewage treatment facility in Sitka, Alaska is designed to discharge only 1.8 MGD.

[10] Sewage from vessels within the meaning of CWA section 312, which includes graywater in the case of commercial vessels operating on the Great Lakes, is exempt from the CWA definition of "pollutant". 33 U.S.C. 1362(6); 33 U.S.C. 1322(a)(6). As a result, vessel sewage discharges are not subject to NPDES permitting. Instead, Congress enacted a separate non-permitting scheme – CWA section 312 – to regulate the discharge of sewage from vessels.

Under section 312 of the CWA, all vessels equipped with installed toilet facilities must also be equipped with an operable U.S. Coast Guard-certified marine sanitation device (MSD). 33 U.S.C. 1322(h). The provisions of section 312 are implemented jointly by EPA and the Coast Guard: EPA sets performance standards for MSDs, and the Coast Guard is responsible for developing regulations governing the design, construction, certification, installation and operation of MSDs, consistent with EPA's standards. 33 U. S.C. 1322(b). Current performance standards which apply to MSDs have standards for solids and fecal coliform. Generally speaking, most MSDs currently installed on study vessels are not designed to remove nutrients from sewage.

Therefore, these estimates are not a complete representation of vessel nutrient loadings; rather, they are merely an estimate of nutrient loadings from incidental discharges.

As described in Chapter, 3 dissolved copper concentrations resulting from study vessels' incidental discharges potentially pose a risk to aquatic life. A significant contribution of the dissolved copper load is from copper leaching from antifouling coatings on vessel hulls. In 2005, the California Regional Water Quality Control Board examined the dissolved copper loads to Shelter Island Yacht Basin from recreational vessel antifouling hull coatings and other source loads in support of a Total Maximum Daily Load (TMDL) analysis for the impaired water. EPA compared the dissolved copper loads from Shelter Island Yacht Basin TMDL to the vessel population scenario loading rates (Table 4.6.2). EPA determined that the estimated dissolved copper loads from 175 to 300 study vessels used in the model (i.e., 2.75 to 4.97 lb/day) were consistent with the combined dissolved copper loads from passive leaching and hull cleaning from 2,363 recreational vessels present in Shelter Island Yacht Basin (i.e., 12.7 lb/day). EPA also compared the model dissolved copper loads to the combined estimated contributions from urban runoff, background, and atmospheric deposition in Shelter Island Yacht Basin (i.e., 0.381 lb/day). The model dissolved copper loads from hull leaching and other discharge streams were significantly larger than the other source contributions present in Shelter Island Yacht Basin, suggesting that dissolved copper from study vessels incidental discharges can represent a significant portion of the dissolved copper load in a water body.

EPA also estimated metal loading rates for urban stormwater runoff based on reported loading rates from a 2001 literature study by Davis et al. and an assumed watershed area of approximately 17 square miles (watershed area determined from readily available information on watersheds' drainage areas for the water bodies discussed in Table 4.4.1). As shown in Table 4.6.2, EPA determined that urban stormwater likely represents a greater load of total copper, total lead, zinc, and cadmium to receiving waters than discharges from 175 to 300 study vessels. However, the model results indicate that dissolved copper loads from study vessels are significant.

Table 4.6.4. Comparison of Model Loading Rates with Other Potential Point Source Loading Rates

Analyte	Model Loading Rates from Vessel Population Scenarios [1]			POTW Loading Rates 10 mg/day[2] (lb/day)	POTW Loading Rates ~40 mg/day[3] (lb/day)	Shelter Island Yacht Basin Loading Rates [4,5,6]					Estimated Urban Runoff Loading Rates [7] (lb/day)
	Fishing Harbor (lb/day)	Large Metropolitan Harbor (lb/day)	Recreational Harbor (lb/day)			Passive Leaching (lb/day)	Hull Cleaning (lb/day)	Urban Runoff (lb/day)	Background (lb/day)	Atmospheric Deposition (lb/day)	
Ammonia as Nitrogen (NH3-N)	8.52	6.07	5.07	8.35-41.7	36.2	NA	NA	NA	NA	NA	NA
Biochemical Oxygen Demand (BOD)	635	481	392	250.4-751.1	NA	NA	NA	NA	NA	NA	NA
Nitrate/Nitrite (NO3 + NO2-N)	0.127	0.203	0.102	NA	1,320	NA	NA	NA	NA	NA	NA
Total Phosphorus	13.8	8.91	7.74	8.35-125.2	22.0	NA	NA	NA	NA	NA	NA
Total Kjeldahl Nitrogen (TKN)	97.8	68.5	59.0	NA	285	NA	NA	NA	NA	NA	NA
Arsenic, Total	0.0279	0.0359	0.0315	0.117-1.17	NA	NA	NA	NA	NA	NA	NA
Cadmium, Total	0.000749	0.000657	0.000551	0.117-0.609	NA	NA	NA	NA	NA	NA	0.032
Copper, Dissolved	2.88	4.97	2.75	NA	NA	12.1	0.604	0.181	0.181	0.0181	NA
Copper, Total	0.158	0.179	0.165	1.25-4.17	NA	NA	NA	NA	NA	NA	1.0
Lead, Total	0.0108	0.0154	0.0142	1.50-4.01	NA	NA	NA	NA	NA	NA	1.8
Zinc, Total	0.758	0.613	0.516	3.34-9.35	NA	NA	NA	NA	NA	NA	17

NA- Not available.

(1) Model loading rates do not include contributions from study vessel sewage waste streams as these discharges are not covered under P.L. 110-299.

(2) Estimated loadings from concentrations for medium sewage treatment facilities (~10 mg/d) derived from concentrations presented in National Research Council (1993).

(3) Estimated nutrient loads from an actual sewage treatment facility with advanced nutrient removal capabilities with an average of approximately 40 mgd discharge (Albert, 2007).

(4) Estimated point source loads to Shelter Island Yacht Basin (California Regional Water Quality Control Board, 2005).

(5) Passive leaching and hull cleaning loading rates were based on an assumption of 2,363 recreational vessels present in Shelter Island Yacht Basin.

(6) Urban runoff contributions were based on a watershed area of 0.84 mi2 draining to Shelter Island Yacht Basin, and the atmospheric deposition loads were based on a surface area of Shelter Island Yacht Basin of 0.27 mi2.

(7) Estimated urban stormwater loads were based on loading rates presented in Davis et al., 2001 and an assumed watershed area of 17 mi2 (MA DEP, 2006).

The loading rates presented are average annual daily loads.

4.7 CONCLUSIONS

This screening-level analysis evaluated the potential for discharges incidental to the normal operation of vessels to pose a risk to human health, welfare, or the environment in large water bodies. The analysis includes all sizes of commercial fishing vessels and other nonrecreational vessels less than 79 feet in length. EPA selected a Level I screening-level model (see Section 4.1) to help assess the potential impacts from study vessels' incidental discharges and modeled several scenarios combining different vessel assemblages and different hypothetical harbors to represent a range of environmental conditions potentially observed in harbors across the United States. The modeled constituent concentrations from the discharges into the hypothetical harbor for the 12 scenarios did not exceed an aquatic life or human health NRWQC solely from study vessel discharges; however, the model did not account for background loadings. Certain pollutants (e.g., arsenic and dissolved copper) are more likely to contribute to a water quality criterion being exceeded under real-world conditions. Furthermore, the model's capabilities do not allow for the evaluation of whether these discharges cause localized impacts (see Section 4.2), nor do they allow an analysis of issues such as bioaccumulation or persistent toxicity in water bodies or accumulation of pollutants in sediments.

As discussed in the introduction, EPA's fraction of freshwater analysis is only intended to evaluate environmental effects from vessel discharges at the water body or harbor scale and does not address the environmental effects that could potentially occur in localized areas such as small side embayments or marinas. As discussed in Section 4.1, the "fraction of freshwater model" does not describe concentration gradients within plumes from vessels. Accounting for spatial and temporal variability in a harbor would require a more data intensive dynamic model and is beyond a Level I screening-level model. EPA acknowledges that incidental discharges from study vessels may pose an environmental threat in confined areas with low receiving water flushing rates and a large population of vessels. In the dilution analysis discussed in Section 4.6, EPA determined that a "tipping point" dilution factor of greater than 358 would be required to avoid exceeding any NRWQC based on the estimated loading rates used in the model (see Table 4.6.1). These results suggest that the loading rates represented in the model may have the potential to cause a water quality criterion to be exceeded on a localized scale either before complete mixing is achieved in the receiving water (i.e., as the plume dissipates) or if the discharges are released in a receiving water with a dilution potential of lower than 358. The model further suggests that these vessels may be more likely to contribute to an NRWQC being exceeded (particularly where the diluting factor is high for a pollutant) where the ambient concentrations or other sources of pollutants are significant. On the other hand, EPA has tended to use conservative estimates of some parameters (e.g., flow and pollutant concentrations) in its modeling.

In the "fraction of freshwater model," EPA calculated the instantaneous concentration in the hypothetical harbor based solely on pollutant contributions from discharges from study vessels. Although the assumption that harbor background pollutant concentrations are zero for all analytes is likely unrealistic, removing other loading considerations from model calculations allows for the assessment of the potential for study vessel incidental discharges alone to cause an NRWQC to be exceeded. Although the “fraction of freshwater model” results suggest that study vessels’ incidental discharges will not cause an environmental impact on their own, the fact that pollutants are present in the vessel discharges at concentrations that exceed the NRWQC at end-of-pipe may support a determination that some of these discharges have the potential to contribute to a water quality standard exceedence.

Based on the dilution results, the two pollutants that represent the greatest risk for contributing to an environmental effect or water body impairment are total arsenic and dissolved copper. EPA determined that the loading rates from the metropolitan harbor (i.e., Model Scenarios 9 and 11) were at the greatest risk of exceeding the NRWQC for these pollutants. However, the minimum dilution factors required to avoid exceeding the NRWQC for these pollutants (i.e., 284 for total arsenic and 144 for dissolved copper in the recreational harbor) are similar to the lowest dilution factor represented in the hypothetical harbor scenarios (i.e., 494). This suggests that study vessel’s incidental discharges may be contributing a significant load of these two pollutants to the water body. Given the right environmental conditions (i.e., low flushing) or pollutant loadings from other point/nonpoint sources (e.g., recreational vessels, large commercial vessels, stormwater runoff, and industrial and municipal point sources), the concentrations of these pollutants may have a potential to cause or contribute to an exceedence of the NRWQC, regardless of vessel class distributions. These results are consistent with real-world observations that metals are frequently associated with vessel discharges in concentrations of potential environmental concern (see Chapter 3). In particular, environmental impacts from dissolved copper leaching from hull coatings has been well documented in low flushing environments such as Shelter Island Yacht Basin near San Diego, California, and Marina Del Rey Harbor in Los Angeles, California.

Nutrients from study vessels’ incidental discharges represent another pollutant class with the potential to contribute to deleterious environmental effects. Nutrients differ from other pollutants present in vessel discharges in that the environmental effects are driven by site-specific environmental conditions (e.g., water temperature, types of algae present, limiting nutrient). For example, the estimated nutrient loads used in the modeling analysis may contribute to an environmental effect in one water body, but not another depending on a variety of factors that control eutrophication. EPA has not developed an NRWQC for nutrients; however, some states have established water-body-specific or state-wide standards for nutrients based on site-specific evaluations.